THE DEPARTMENT OF DEFENSE

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

FISCAL YEAR 1979 PROGRAM FOR RESEARCH AND DEVELOPMENT

STATEMENT BY THE DIRECTOR OF THE DEFENSE ADVANCED RESEARCH PROJECTS AGENCY TO THE 95th CONGRESS SECOND SESSION 1978

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DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

FISCAL YEAR 1979 RESEARCH & DEVELOPMENT PROGRAM

STATEMENT

BY

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DIRECTOR

BEFORE THE SUBCOMMITTEE FOR RESEARCH & DEVELOPMENT OF

SENATE ARMED SERVICES COMMITTEE

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Mr. Chairman, it is my pleasure to present to this Committee the budget request of the Defense Advanced Research Projects Agency (DARPA) for FY 1979. Since this is my first appearance before this Committee as the Director of DARPA, I believe it appropriate to provide some background on my professional experience and philosophy relevant to the Defense Advanced Research Projects Agency and to research and development in the Department of Defense.

My professional experience, mainly in the private sector, has been in analysis, conceptualization, development and production of electronic warfare and surveillance systems. Most recently, I served as the Dean of Science and Engineering at the U.S. Naval Postgraduate School.

I bring to DARPA an experienced appreciation for the power of technology, but I also bring what I consider a healthy skepticism that technological advances alone can solve all problems; that technology for technology's sake is justifiable. I believe, therefore, that investments in research and advanced technology for national defense should be carefully examined to assure the returns in the way of measurable increases in defense capability justify those investments.

I am happy to have the opportunity to serve as Director of DARPA. I have worked for DARPA, as well as all of the Military Services, from the other side of the fence, so to speak. This experience has convinced me of the unique benefits and essentiality

of a highly flexible research activity which responds directly to the highest officials of our Defense establishment and undertakes the "revolutionary" as opposed to "evolutionary" technology initiatives. There is no substitute for research thrusts that cut across role and mission boundaries, that telescope evolutionary processes, that deliberately attack the far-reaching, usually risky, but high potential payoff technology initiatives, and that have the freedom to fail. DARPA has those missions and those charters from the Department of Defense and, as such, is unique in the federal service.

One has only to consider a few of the past accomplishments of DARPA in ballistic missile defense, in computer science, in sensors, and in materials to reckon the national benefit of this unique research organization.

I have carefully reviewed the FY 1979 DARPA budget request that I am submitting today, and I believe that each technical initiative represented in this budget satisfies the criteria I previously mentioned for a measurable and significant return in the way of increased defense capability.

The major thrusts of the DARPA program presented to you last year are, with some exceptions, being continued. I would like to briefly review with you the results that have been achieved in each of these thrust areas and the plans for FY 1979 those results suggest.

1. Space Defense

Last year we described some early conclusions reached concerning the applications of high energy lasers in space. Since then we have broadened the examination of the capabilities of this technology and have concluded that lasers have unique and high pay-off potential for some space applications. We have also made substantial progress this last year in advancing the technology base in space-related laser devices and optics technology.

The vacuum of space offers the potential for full utilization of the unique characteristics of laser radiation - the ability to propagate long distances with minimal spread of the laser beam. This property is degraded within the earth's atmosphere by absorption and turbulence effects which reduce the range over which effective communication can be maintained. In addition, some laser devices are able to achieve significantly higher efficiency in the low pressure space environment than is available at or near atmospheric pressure.

The DARPA high energy laser program is concentrating on the development of efficient infrared chemical and visible electrical laser technologies as well as precise pointing systems and large optics required to take advantage of this space environment. Major feasibility demonstrations are being initiated to establish the practicality of laser systems to achieve the performance levels required for space applications. We are requesting $44.0M, for the FY 1979 program to continue the space-related

technology development and to proceed with these major feasibility demonstrations.

2. Space Surveillance

Our national ability to conduct effective surveillance of missile launches and space objects is an absolutely essential ingredient of our strategic defense posture, both for early warning of hostile action and for assuring compliance with any treaty dealing with limitations on strategic force capabilities. Space-based infrared surveillance systems to provide early warning detection of ICBM launches were demonstrated a decade ago and exist today in operational systems. These systems, however, have inherent limitations which impact their effectiveness.

We believe that these deficiencies can be eliminated through the use of the advanced infrared detector array technology being developed by DARPA. We are developing a technology base that keeps the cost of these focal planes within that of current systems, while providing substantial improvements in launch warning capability.

We have begun construction of a satellite-based experiment to demonstrate the concept of aircraft detection from space. This experiment was made possible by recent accomplishments in focal plane arrays. Known as the DARPA TEAL RUBY Experiment, this sensor will provide basic experimental data and is scheduled for launch into a low altitude orbit by the Air Force in March of 1981.

Our next step in technology development for advanced focal planes is underway in the High Altitude, Large Optics (HALO) program.

The key element here is the design and development of extrinsic silicon monolithic detector arrays for low detector cost and high performance. Special spectral filters and signal processors are being developed as well.

Our progress in this technology development includes the successful design and laboratory demonstration of on-chip detector circuitry, high fabrication yields and performance for detector arrays, the successful demonstration of spectral filters closely matching the theoretical model and the design and simulation of key signal processor functions at the required level of performance. With these results from critical technology requirments, we feel confident that the level of component sophistication necessary is feasible. Consequently, we have initiated the design of a proof-of-concept demonstration called the Mini-HALO flight demonstration, scheduled for launch by the Air Force in the early 1980's. It is our objective that this experiment demonstrate an enhanced capability for detection of missiles and the use of DARPA-developed focal plane technology. It will be timely in providing technological and mission alternatives to the Air Force for decisions in the mid-1980's on the next generation missile early warning systems. The experiment will not have the capability to perform the functions for which the TEAL RUBY sensor has been designed.

In FY 1979 we are also investing in radar and radiometric technology to provide a technology base from which to assess the

feasibility of active sensor technology for strategic target surveillance.

We are requesting $59.0M for our overall Space Surveillance thrust.

3. Cruise Missiles

This is a new major initiative being undertaken in response to direction of the Under Secretary of Defense for Research and Engineering to provide the technology base for future improvements in cruise missile range, payload and guidance capability. It is based largely on earlier DARPA seed efforts, and we are requesting an increase of $8.2M for a total budget of $23.2M to adequately pursue these important technology options.

First, in advanced vehicle designs and launch modes, we are developing a variety of subsystem technologies in airframe materials and configurations. During FY 1978, a number of airframe concepts are being analyzed and evaluated exerimentally. Beginning in late FY 1978 and into FY 1979, activities will include wind tunnel tests, structural tests, and critical subsystem developments. On a companion effort, advanced engine concepts are being investigated to improve the fuel consumption of small engines. In FY 1978 and FY 1979, we are examining the critical technical issues associated with high temperature, high pressure ratio, engine designs by means of analysis and component testing. In FY 1979, test devices will be fabricated and tested. The related efforts in vehicle designs and engine concepts will provide DARPA with the demonstrated technology base to support

the selection of optimum configurations yielding improved range-payload products.

Secondly, advanced self-contained, adverse weather capable, guidance techniques are being pursued which will enable new cruise missile mission options to be developed for strategic theater targets. During FY 1978, ground-based and airborne sensor systems are being developed to collect the data base which will enable the assessment of possible guidance systems characteristics with only one variable changing at a time. In FY 1979, we will proceed to the development of flyable brassboards of the 2 or 3 most promising concepts.

Finally, a program is being initiated to characterize and assess cruise missile defense technologies. The program will include analysis and field measurements to resolve basic effects associated with surveillance, acquisition, track and intercept of cruise missiles.

4. Anti-Submarine Warfare:

The Soviets are aggressively pursuing a program to render their attack submarine forces less susceptable to detection. To counter this potential threat the Director of Defense Research and Engineering requested in 1975 that DARPA initiate an intensive research effort to determine the fundamental physical and technological limitations on undersea acoustic surveillance and exploit advanced signal processing, passive receiving array technology and active surveillance techniques. This project, named SEAGUARD, was begun in FY 1975.

In order to carry out this research, we established the Acoustic Research Center (ARC) at Moffett Field, California, to permit experimental evaluation of advanced signal processing techniques in submarine detection and localization. This DARPA supported installation is the most advanced facility for the conduct of acoustic undersea detection research in the nation and we are justly proud of its performance to date. We have achieved a fundamental understanding of ocean physics and are now operating the ARC on a daily basis; evaluating detection and tracking capabilities with controlled fleet exercises, surface targets of opportunity and patrolling submarines. Along with the basic research, we are testing some arrays employing passive acoustic detection techniques. As an alternative to passive acoustic techniques, we will also investigate in FY79 the technique of employing an explosive or active source to determine the optimum reverberation levels for surveillance.

Our investigation into detection techniques continues. It is our hope that some new techniques will evolve that can then be examined for future application in localizing and targeting enemy undersea vehicles. Our FY 1979 program in anti-submarine warfare is planned at $40.0M. It will be directed towards continuing our research and conduct of experiments by the Acoustic Research Center (ARC) emplanting a horizontal acoustic array; initiating fabrication of a vertical array and deployment of a dummy to determine tradeoffs in the design of future arrays; conducting an at-sea surveillance test to determine feasibility and, if warranted, initiating development of an air gun array impulsive source; and continuing at-sea detection experiments to

determine feasibility of various anti-submarine warfare techniques.

5. Land Combat:

The land forces of the Soviet Union represent one of the most critical threats currently facing our operational forces. Not only have the Soviets fielded overwhelming quantities of land combat vehicles and weapons and related material, but we also observe an ever-increasing quality and capability in that material. We are requesting $32.0M in this area to emphasize on-going efforts that can help to significantly offset the potential imbalance we perceive in the land battle. I'd like to describe some of the major efforts.

As you know, we have been pursuing an aggressive program in concert with the Army to develop a revolutionary 75mm anti-armor automatic cannon, testbed armored vehicles that employ that gun, and an effort to quantify the tactical utility of that type weapon, coupled with other system parameters such as: high agility/mobility, light armor, various fire control schemes. In response to Congressional direction during the FY 1978 Appropriation process, we have accelerated the development of the automatic 75mm cannon and ammunition system to advance the date by which that system will be suitable for troop tests by three years. I'm happy to report the Army and Marine Corps have intensified and accelerated their efforts in this Advanced Combat Vehicle Technology initiative. The Chief of Staff of the Army has personally taken extraordinary steps to assure that answers to key questions which will determine future full scale development directions

are collected as early as possible. Through those efforts we have advanced by one year our planned transition of this vital effort to the Services. We plan to continue to support and participate in this effort but the main impetus has been picked up by the Services.

One of the most difficult and chronic problems in managing the land battle has always been the integration of intelligence data, target sighting, and other indicators, into near real-time target files to enable the field commander to best allocate available forces. During this past year we have initiated a research effort to demonstrate in an operational arena that technology now available can greatly reduce that problem. A joint Army/Air Force/DARPA program to develop a system for Battlefield Evaluation of Target Acquisition (BETA) data at the operational commander's level has been initiated. The objective is to test and demonstrate this system in the European Theater. This is a very ambitious undertaking, but one well worth the risk because of the high payoff in terms of optimum allocation of tactical resources in the face of a numerically superior enemy. Other initiatives we are pursuing as part of our major threat on the land combat problem include:

o The development of processes to permit netting battlefield surveillance radars to increase overall area effectiveness and allow failures of individual radars without loss of coverage.

o Experiments to determine the utility and limits of bi-static radars for battlefield usage. This technique offers the

possibilities of protecting users from radiation seeking weapons by locating the illuminator or transmitter remote from the user.

o Research on advanced warhead technology to achieve greatly increased target penetration with warheads and a fuel air explosive munition for area type tactical targets.

6. Air Vehicles and Weapons:

This is a new major thrust for DARPA which has emerged as a result of successes in seed efforts we described in our statement to you last year. Initial investigations of two revolutionary aircraft concepts, application of infrared space surveillance technology to tactical missions and a self-initiated multi-mode anti-aircraft missile have shown sufficient promise to justify exploratory development of test models to demonstrate what appears to be significant new capabilities in air warfare. I would like to more fully describe each of these.

o X-Wing - This is a concept which combines in one air vehicle the capabilities of a helicopter and high sub-sonic speed fixed wing aircraft. Analysis and extensive wind tunnel tests have validated this technique. Flight vehicle designs and scale model tests indicate that the X-wing offers high payload, good hover and low speed handling, low downward velocities, low noise and gain in mission range over standard helicopters. A full scale rotor hub and flight control system is being fabricated to verify the in-flight transition. If these tests are successful a flight demonstrator will be fabricated for flight tests by end of FY 1979.

o Forward Swept Wing - Analysis shows that forward swept, rather than aft, air vehicle wings increase wing efficiency and correspondingly, the ability of aircraft to perform high 'g' maneuvers. In the past, forward swept wings were precluded because of prohibitively heavy structural members in wing designs. The advent of practical composite structures however, now makes it possible to solve the divergence problem in a practical wing structure and exploit the potential performance gains of forward swept wing aircraft. We have initiated wind tunnel tests and comparative analysis with swept back wing designs. In FY 1979 we plan structural tests and will design a demonstration flight vehicle if results continue to be positive.

o Tactical applications of infrared Space Surveillance Technology - Successes in fabricating high density storing versus scanning infrared images now offer the possibilities of fire and forget seekers which are low in cost and permit central impact of ground targets immersed in high clutter. The same basic technology permits the development of very high performance target acquisition devices for potential use with the advanced seekers and as candidates for a new generation of tactical forward looking infrared imagers. Models of both devices are being fabricated for field tests in mid-FY 1979.

o Self-Initiated Anti-Aircraft Missile (SIAM) - This is a missile which, when initiated, independently searches for and locates the most imminent helicopter or fixed wing threat during ascent by means of a radar sensor. Upon acquisition, the missile

pitches over and tracks the target. In FY 1979 full scale tests against drone targets will be conducted. This weapon is of particular interest to the Navy to provide submarines with the capability to counter anti-submarine warfare aircraft attempting to localize or attack. SIAM is a joint program which is expected to be fully transferred to the Navy by the end of FY 1979.

I believe you would agree our new thrusts in air vehicles and weapons offer some exciting new possibilities. In order to pursue these efforts we are requesting $34.0M for FY 1979.

7. Command, Control and Communications:

The central function of Defense Command and Control is to manage and coordinate military resources which may be located at any point on earth. The force multiplier effect of modern, adaptable command and control systems is crucially dependent on reliable, rapid and flexible communications; powerful information processing capabilities to handle the massive flow of information needed to support military operations; and techniques which optimize the use of information to manage crisis and formulate decisions.

In last year's testimony, we outlined a unique approach toward the development and demonstration of advanced technology in each of these C^3 areas.

The focus of this approach is to:

o Complete the technology base for modern command and control by integrating emerging technology in computer science,

communication, and information processing.

o Provide a testbed environment on which to evaluate alternative C^3 architectures as a basis for designing operational systems utilizing empirical data.

o Close the gap between the system engineer and the user and accelerate the transfer of technology into an area in which technology transfer has been slow and inefficient in the past.

Filling the gaps of the technology base involves the pursuit of several technical initiatives:

1. Reliable, secure digital communications are the foundation of modern C^3 systems. Advanced Communications research is applying the demonstrated success of packet-switching in the fixed ARPANET environment to the development of multi-destination packet switched communications satellite technology, the development of a mobile computer-communications system based on a packet radio concept, suitable for support of tactical operations, and the demonstration of narrowband speech across a packet-switched network. Tying the capabilities of terrestrial, satellite, and packet radio networks together is an internetting program which permits the smooth interconnection of dissimilar computer-communications networks.

2. The efficient, timely, and accurate use of information provided to a Commander and his staff requires improved man-machine interfaces and automated decision aids. We are building the base for these capabilities in providing aids for crisis

management, decision aids, and a new technology for information management.

3. Future decisions will require more and more the use of large data bases by users distributed around the world on computer-communications networks. We are pursuing efforts to fill the technology gap in this area by developing and demonstrating the use of a natural language interface to a distributed data base system, network graphics, and improved data base systems capable of intelligently assisting a user in retrieving information.

4. Security of computer-communications networks and the host computers attached to these networks is essential to supporting military operations. We have a number of joint efforts in progress with Defense Agencies and the Services addressing computer network security technology and techniques to provide multi-level secure operation of military computer systems.

We are pursuing several testbed activities as a means of evaluating technology and facilitating transfer to a using Service. The first increment of an Advanced Command and Control Architectural Testbed is in operation at the Naval Ocean Systems Center in San Diego. This joint activity with the Navy serves as a flexible design tool for determining the architecture and function of future (1985-1990) C^3 systems and for evaluating the technology upon which future systems will be built before making hard and costly deployment decisions.

A joint DARPA/Navy/CINCPAC Military Message Experimental System has been installed at CINCPAC. A two-year experiment will continue through FY 1979 to evaluate the utility of secure interactive message communications systems in a military environment.

A joint DARPA/Army Tactical Data Distribution Experiment has been initiated in FY 1978 to examine the use of packet radio networks to meet command and control data distribution needs of Army operations in a theater. Over the FY 1979-81 period, the results of this testbed program would provide the basis for developing requirements for future Army Tactical Data Distribution Systems.

We are using these testbeds as a means of bringing real user communities into direct contact with advanced technologies. User reactions provide an important feedback to system designers as well as providing a realistic assessment of the cost effectiveness and utility of possible architectural alternatives. We are requesting $40.0M for our command and control related efforts in FY 1979.

8. Nuclear Test Verification Technology:

By interagency agreement in the early 1960's, the DoD accepted responsibility for research to improve national nuclear test detection and monitoring capability. DARPA was assigned this mission for the DoD. We have been following a research plan designed to resolve by the end of FY 79, the more critical problems of reducing the uncertainty in seismic yield estimation and improving discrimination between earthquakes and underground explosions in the low kiloton energy range. Current test ban treaty negotiations, however, have focused attention on deficiencies in detection, identification and yield verification which still remain, and which do not appear amenable to solution in the near term. At the direction of the Secretary of Defense, we are requesting $10.0M in order to undertake an enhanced test detection and evaluation research program, and are not phasing down this research thrust in FY 1979 as originally planned. The major effort in this new initiative will concentrate on determination of yields of underground explosions, and on detection and identification of underground explosions at distances appropriate to monitoring stations inside the territories of nuclear powers. This program will be supported by studies in counter-evasion, advanced detection systems, and fundamental seismological studies of the generation, propagation and measurement of seismic waves.

9. Lowering the Cost of National Defense Through Technology:

Within the Defense Department, there is a continuing intensive effort to reduce operating costs and acquire the most cost effective materials. The DARPA contribution to this major thrust is to explore radically new material designs, and techniques that have across the board potential for cost reduction. Examples of activities and accomplishments are:

1. We have achieved a major milestone in the application of ceramics to gas turbines. For the first time a turbine with a full ceramic core and rotor, was operated for a sustained period (100 min) at rated speed (50,000 rpm) and to the best of our knowledge the highest inlet temperature (1370^{o}C) ever achieved with uncooled blades. This achievement may well set the stage for a new era of lower cost, more efficient and higher performance gas turbines suitable for many military applications and even more civilian uses. Because of the latter possibilities, this is now a joint venture with the Department of Energy.

2. In a more direct attack on the superalloy barrier we have concentrated efforts on powder metallurgy and broken an 18 year pause in significantly improving superalloy temperature limits. By virtue of cooling micron size molten metal powders at rates of 100,000^{o}C per second, we have suppressed harmful crystalline segregation. By this technique we have demonstrated a 50^{o}C improvement in temperature capability and a ninefold

improvement in fatigue life of the nickel-base superalloy used for F-100 turbine blades.

3. In computer software technology, DARPA is assuming one of its classic roles as a catalyzer for the entire DoD. The potential for cost savings in software required for Defense systems is enormous. While there are technology issues involved, the generic problem is one of establishing commonality in the use of proven techniques, insuring that state of the art software engineering tools are available to Defense systems developers and that new software technology is introduced by an orderly process. DARPA chairs a DoD Software Technology panel to achieve these goals. Utilizing the DARPA nationwide computer net, a system now called the National Software Works is being created. This will provide a repository for DoD owned software development and maintenance tools, and means to introduce new software techniques. These will be available to all Defense Systems developers. I cannot overstate the potential payoff of the research investment we are making in computer software. There are many examples of excess cost, delays and performance problems in major weapon systems as a direct result of problems in embedded software. The accomplishments to date from this DARPA research, and the tools and techniques that will be available when it is completed, will definitely minimize if not eliminate those occurrences. The cost saving can easily be in the 100's of millions of dollars.

These are only a few examples of the application of revolutionary ideas and technology to the overall DoD goal of national security at least cost. Other research initiatives include: quantitative non-destructive evaluation, application of unprecedented incentives in maintenance of high value equipment, computer aided engineering of critical but low volume integrated circuits and computer based training techniques. For FY 1979 we are requesting $16.0M to continue this important and high payoff effort.

10. New Technology Initiatives and Seed Efforts:

While we have prioritized the DARPA program into major thrusts areas, we recognize a parallel obligation and necessity to explore and nurture new and innovative ideas to continually replenish our technological shelf. Some will be discarded, some will prove sufficiently promising to justify a major follow-on program.

During the past year several seed efforts, started in late FY 1977, have proven sufficiently promising to become the basis of a major effort. Among those that I have already discussed are:

1. Autonomous Terminal Homing, now being pursued as a major element of our Cruise Missile Technology thrust;

2. The X-Wing and Forward Swept Wing Aircraft;

3. The Self-Initiated Anti-Aircraft Missile; and

4. The application of infrared space surveillance technology to fire and forget missiles and advanced forward looking infrared systems.

In FY 1979 we are planning to undertake seed efforts on some exciting new ideas. I'd like to describe two that are particularly promising.

o Assault Breaker - This is a unique concept, based on the integration of a number of emerging technologies, to achieve a non-nuclear response to massed armor with radically increased kill effectiveness. The concept includes a near forward edge battle area surveillance aircraft containing both active and passive, all-weather sensors which perform continuous battle front surveillance as well as midcourse command guidance for standoff weapons. A ground fire control center is included which uses the sensor data to identify target areas and guide cluster munitions to target areas. Studies show the Assault Breaker concept is feasible. The critical technology issues have been identified and will be investigated by means of brassboards and field tests in FY 1979. If these barriers can be overcome and the concept continues to show promise, the evolving system design will be fabricated for a full scale demonstration in FY 1980/81. This is expected to be a joint Air Force/DARPA program.

o Laser Communications - This is a possible future, high risk alternative to current communication technques.

Other new ideas or seed efforts we plan to undertake include:

1. Human Memory Augmentors
2. Optical Ceramics
3. Expendable electronic warfare jammers
4. Adaptive computer internetting
5. Focussed Ion Beam Processing
6. Biocybernetic Avionics

For FY 1979 we are requesting $33.9M to allocate against new ideas or seed efforts.

B. Conclusion

Mr. Chairman, I've attempted to provide the strategy and rationale for the R&D investment the DARPA program represents. I've addressed the highlights and accomplishments of the current program, and from those the basis for our FY 1979 budget request. In succeeding sections of this statement there is provided much greater details on the nature and dynamics of all the programs I've discussed.

As I stated at the outset, in my view R&D investment decisions must be carefully considered to avoid a natural inclination of technologists to advance technology for its own sake. Clearly there are institutions and activities where that is appropriate, but I do not believe it is so for DARPA. We have carefully reviewed the programs for which we are requesting funds in FY 1979. I believe they all represent initiatives which, if successful, will make a quantifiable difference in our national defense capability and our understanding of what capability may be possible in the future.

Though I am a new man on the block, I am very excited about the technological successes that DARPA has achieved during the past year, particularly in the areas of space surveillance, high energy lasers, air vehicles and armored combat vehicles. In order to capitalize on some of these basic technology advances we must now design, construct and evaluate meaningful, full scale experimental systems. We cannot truly advance many of these technologies by continuing component research subsystem experiments. This means higher costs and you see that reflected in the increases we are requesting for the FY 1979 DARPA

program. These increases, over the previous year's request, are predominately in the exploratory development program element entitled "Experimental Evaluation of Major Innovative Technologies." We have prioritized our overall program to shift resources where possible to make up some of the needs. However, we believe we have gone as far as we can and should go without completely giving up many longer term new ideas which should be carried out. The Secretary of Defense and Under Secretary for Research and Engineering are fully supportive of the DARPA programs and particularly those initiatives aimed at making a meaningful assessment of new innovative high risk/high payoff technology before major developmental commitments are considered.

The details of our proposed FY 1979 program, as well as achievements of the past year, are contained in the following sections.

II. THE DARPA BUDGET REQUEST - FISCAL YEAR 1979

The funds we are requesting to carry out the DARPA program outlined in the preceding section represent an increase of $50.5M, or an 11 percent increase in real terms over our approved FY 1978 program. As shown on the following table, the preponderance of this increase occurs in program element 62711E, Experimental Evaluation of Major Innovative Technologies, and, within that element, three new experimental efforts in Space Surveillance and Space Defense require $27.6M of the increase. Prior research in these vital areas has produced technology building blocks which are sufficiently mature to justify the investment we are proposing to validate and demonstrate the revolutionary new system capabilities those research achievements promise. The marginal return from further research is decreasing. We have reached the point where the greatest technological gains can be realized only by applying our state-of-the-art knowledge in practical demonstration systems.

Changes in other program elements that I would like to bring to your attention include: (1) A new orientation in our Nuclear Test Verification Technology. We are completing in FY 1979 all exploratory development activities in nuclear test monitoring and initiating a concentrated research effort on detection yield estimation and counter evasion which will expand and continue in future

years. This change is in response to a Secretary of Defense request for a continuing research effort that will assure a sound technical basis for U.S. positions in test ban treaty negotiations and strengthen our capability to verify adherence to any resulting agreements; (2) Significant increase in level of effort on Unconventional Detection Research; (3) An increase in technology for efforts concentrated on technologies to support future generations of cruise missiles; and (4) An increase in our Tactical Technology element which is largely to support our new initiative in Assault Breaker.

From an overall point of view, the funding resources we are requesting will allow us to carry out a carefully conceived research and exploratory development program that does address critical defense needs and which, if successful, would significantly enchance our nations's security. The proposed program represents a deliberate balance among new research initiatives, a continuation of very promising advanced technology and efforts to exploit technological advances in meaningful demonstration systems. These three categories represent 18, 54, and 25 percent of our FY 1979 request.

The following table extracted from the Justification of Budget Estimates, separately submitted to you, shows our budget request for FY 1979 by program element and sub-element. I have also included actual funding expended in FY 1977, estimated expenditures for FY 1978 and an estimate of FY 1980 requirements.

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY
SUMMARY OF FUNDING
($ in Thousands)

Program Element	Title	FY 1977 Actual	FY 1978 Estimate	FY 1979 Estimate	FY 1980 Estimate
61101E	Defense Research Sciences	$ 35,090	$ 42,017	$ 49,100	$ 66,200
	Materials Sciences	(16,236)	(15,700)	(16,600)	(19,200)
	Cybernetics Sciences	(2,665)	(4,667)	(5,000)	(7,400)
	Computer & Communications Sci	(14,334)	(17,650)	(17,200)	(20,100)
	Advanced Geophysical Concepts	(200)	(500)	-	-
	Unconventional Detection Res	(1,655)	(3,500)	(6,100)	(9,500)
	Nuclear Test Detection	-	-	(4,200)	(10,000)
62101E	Technical Studies	2,300	2,500	2,900	2,900
62301E	Strategic Technology	76,683	85,700*	91,500	111,900
62701E	Nuclear Monitoring Research	12,386	10,000	5,800	-
62702E	Tactical Technology	66,255	73,008	78,600	88,700
62706E	Distributed Information Systems	8,983	8,102	8,200	8,800
62708E	Advanced Command, Control and Communications Technology	11,310	11,100	13,000	14,000
62709E	Systems Cybernetics Technology	5,560	4,524	4,300	3,200
62711E	Experimental Evaluation of Major Innovative Technologies	4,005	39,850	73,600	92,000
62712E	Materials Processing Technology	8,555	5,005	5,100	7,400
65898E	Management Headquarters (R&D)	4,273	4,700	4,900	4,900
	TOTAL DARPA	$235,400	$286,506	$337,000	$400,000

* Includes FY 1978 supplemental appropriation of $9.0 million.

III. ACCOMPLISHMENTS - This section is intended to provide a capsule report on the output and dynamics of the DARPA program during the past year. It is by no means a complete statement of all achievements, rather it represents a selection of activities we consider significant. The period covered includes the last half of FY 1977 and the first half of FY 1978. Three categories of activities are presented: (1) Technological achievements, (2) programs transitioned to others for follow-on research or systems development, and (3) programs terminated.

A. Technology Achievements

1. High-Power Chemical Lasers - The high-efficiency, low-pressure chemical laser is a promising device for high-power space applications. Last year we demonstrated low-pressure, high efficiency laser operation in small scale nozzles. This year, we are scaling up this nozzle technology. We have also succeeded in a recent demonstration of a fundamentally new approach to chemical lasers that relaxes fabrication requirements, produces a longer, more usable gain region, and in small scale, showed high efficiencies.

2. High Power Electrical Lasers - The thrust of this effort is to develop the technology base which will establish the feasibility of high-power electrically driven visible lasers. This approach offers substantial advantages for long-range space applications. We have accomplished key milestones in this effort.

3. Advanced Infrared Focal Plane Arrays - Operation of these arrays was demonstrated in FY 1977. The high manufacturing yields predicted for low cost, operational infrared systems was achieved. Designs of on-chip circuits for the High Altitude Large Optics (HALO) detector arrays are complete and are being evaluated. Designs for the HALO arrays will be initiated after the circuit evaluation is completed. The susccessful development of these arrays will enable the construction of the next generation of strategic surveillance sensors at costs comparable to the current sensor focal planes.

The aircraft signature measurement program has produced the first field data of the in-flight infrared signature of an aircraft under cruise conditions. These field data provide experimental evidence for the plausibility of the sensor approach to detecting aircraft that is the basis of DARPA's infrared surveillance technology program. A full proof-of-concept demonstration will be accomplished with the TEAL RUBY Experiment.

4. Lightweight Optics - Two critical milestones were achieved toward the optical concepts needed for large, wide field-of-view surveillance systems. First, two unique optical designs were completed, meeting the performance requirements for the advanced surveillance concepts; until these results were obtained, no satisfactory optical form existed. Secondly, a test piece was fabricated and tested incorporating the physical characteristics

necessary for the advanced surveillance application; the critical issue of construction techniques was settled by the success of these tests.

5. Long-Range Imaging Radar Accomplishments - The DARPA long-range imaging radar (LRIR) program has been developing the hardware and techniques for the identification of space objects. Processing techniques developed under previous radar programs were adapted to verify the performance of the radar. Compensation calibration integration techniques were developed which allowed efficient target tracking.

6. Membrane Mirror Concept Evaluation - The analytical evaluation of light weight membranes produced surprisingly promising results for so radical a concept in early FY 1978. A relatively small number of control devices can shape a membrane to an optically useful figure. Weights are anticipated to be significantly less than current glass mirror technology. Dynamic effects on the membrane surface are less than previously expected and well within acceptable bounds. An initial experiment to verify these analytic results is underway. The membrane concept, while initially considered for infrared optics, appears well suited for radio frequency antennas as well.

7. Fixed/Mobile Experiment (FME) - The Fixed/Mobile Experiment (FME) conducted in the Fall of 1976, clearly demonstrated that arrays can be used with advanced processing techniques to provide substantial improvement to system localization and detection

performance. Continuing analysis at the Acoustic Research Center (ARC) of the data gathered during the FME has led to a greatly increased understanding of the potential and limitations of advanced processing. Since the type of processing used does not make any assumptions concerning the nature of the signature, it is much less sensitive to signal properties than the single array processing systems. A strong signal on one array can be used to dig out an ordinarily undetectable weak signal on a second array. The FME has already shown that we can use other arrays to overcome geometrical limitations of existing fixed arrays. These results are providing the basis for focussing our advanced processing activities and planning major experiments.

8. Anti-Tank Anti-Aircraft Defense System (ATAADS) -An advanced, lightweight guidance unit applicable to small tactical missiles has been built and demonstrated. This unit is a key component of a lightweight, one-man portable, dual-purpose missile system which, when developed, could significantly improve the assault and defensive capability of our military forces. Missile electronics measure pitch and yaw information to correct flight path. A sightline stabilizer to filter out jitter and direct view sighting completes the system. Preliminary tests indicate the sight markedly improves gunners' tracking accuracy and average deviation of the missile from the laser beam center.

9. Advanced Warhead Technology Program kinetic energy (KE) penetrator failure mechanisms have been modeled. The computer codes

have shown that failure of the KE round is due to loss of material on impact and introduction of severe bending moments in the back end of the penetrator. Detailed analysis of the codes has led to new penetrator designs. Tests with 1/10 and 1/4 scale model penetrators have shown improved penetration using the new designs.

10. New Advanced Warhead designs have been developed. The cone material is improved to provide "behind-the-armor" effect. Some new designs use at least 50 percent of the mass of the cone in the jet.

11. Packet Satellite Technology - A packet satellite system, consisting of three large earth stations operating at 64 kilobits per second and one small station operating at 16 to 32 kilobits per second has been installed between Etam, West Virginia; Goonhilly, England; Tanum, Sweden; and Clarksburg, Maryland. Performance experiments with simple channel allocation strategies have been conducted using the large station. A contention, priority-oriented, demand allocation (CPODA) channel access scheme has been implemented and is under test. Simulations of CPODA indicate it should be efficient for mixed voice and data traffic.

12. Packet Radio Technology - An experimental packet radio testbed with 20 packet radio units has been installed in the San Francisco Bay area. A second station has been installed in preparation for multistation tests. Microprocessors

have been programmed to act as internetwork terminal controllers so that fixed and mobile terminals can access ARPANET resources via the packet radio network/ARPANET gateway. Fixed-to-mobile and mobile-to-mobile computer communications have been successfully demonstrated in multipath environments. The ability of the radio net to automatically reconfigure itself as radios are moved has been demonstrated in mobile experiments.

13. Natural Language Access to Command and Control Data - We have a prototype natural language system, called LADDER, "Language Access to Distributed Data With Error Recovery," operating today which is capable of responding to a wide range of English queries related to the status of Naval forces. It is based on artificial intelligence techniques developed under DARPA sponsorship over the past decade. The prototype LADDER system uses the ARPANET to communicate with geographically separated data bases, each of which contains part of the data which is needed to respond to some of the queries.

14. Synthetic Photography - An experimental computer program has been developed which generates synthetic photographs from terrain elevation maps. These synthetic photographs can be matched to terrain imagery almost as well as real photographs taken on-site with a camera. This technology will make it possible for vehicles to navigate by matching sensed photos against terrain maps instead of matching against prestored photographs.

15. Focused Ion Beams - In late FY 1976, DARPA initiated a "seed" program to explore the feasibility of using intense, highly focused ion beams in the processing or fabrication of microelectronic structures. This unique program exceeded its first phase goals by achieving an ion current of 5×10^{-9} amps in a spot approximately 0.6 microns (6×10^{-5}cm) in diameter. The spot sizes and current densities demonstrated (hundredfold improvement over previous results) are suitable for use in microcircuit fabrication processes, such as direct formation of device and integrated circuit structures without the use of photomasks. Such a capability will revolutionize the processing of low volume (by commercial standards), high performance devices and microcircuits which frequently are precluded from use in DoD systems due to cost and development times associated with custom design and processing.

16. Ceramic Turbine - The automotive ceramic turbine program being conducted jointly with the Department of Energy achieved a highly significant test milestone during the year. An engine with a full ceramic core and rotor achieved full-bore operation (1,370°C and 50,000 rpm), developing 65 horsepower for 100 minutes across a single rotor stage.

17. Strong Optical Fiberguides - Strong optical fiberguides coated with aluminum have achieved a lifetime of over nine months in water at six percent strain. Current commercial uncoated fiberguides would last only approximately 60 seconds

even if fabricated of the best glass ever demonstrated. Development of process quality control to achieve the above strain-lifetime combination of ten kilometer fibers appears feasible, and will allow incorporation of optical fiberguides into military systems where the marine environment is a dominant factor, such as towed arrays, hydrophones, and wire-guided torpedos.

18. High-Rate Powder Development - The production of powders in the micron-size range at cooling rates exceeding 100,000°C per second has been achieved. This offers a revolutionary means of not only suppressing undesired segregation, but also of greatly extending options for improved alloy development. By means of this technology, a 50°C improvement in the temperature capability and a ninefold improvement in the low cycle fatigue life of IN-100, the F-100 turbine blade superalloy, have been achieved. Thus, the 18-year pause in significantly improving superalloy temperature capabilities has been broken.

19. Cybernetics of Instructional Systems - Evaluation results are very positive from projects to teach intellectual and affective skills. In one case in which intellectual skills were taught (e.g., comprehension, textual materials), data indicated a 200 to 400 percent improvement compared to a control group that did not receive such training. Further, this improvement was made without negative consequences (e.g., increases in anxiety). In another case in which time management skills were taught, data

on time reduction in a computer-based training environment indicate that overall time was reduced 11 percent compared to the control group. This control group (in a computer-based training situation) already had reduced training time by 40 percent compared to prior lecture/discussion techniques.

20. Biocybernetics - There have been a number of major accomplishments in the biocybernetics program for extracting useful information from the electroencephalogram (EEG) and other nonverbal signals. Most significantly, a new method has been demonstrated for the measurement of workload or cognitive load, allowing a system designer to assess the spare capacity of an operator on a moment-to-moment basis and without interfering with the performance of his task. Such a workload measure can be used for performance measurement and enhancement, for equipment design, and for personnel selection. A new technique has been demonstrated for measuring components of the electroencephalogram associated with decision making and with action. When people are asked to perform tasks at high speed, the components of the electroencephalogram associated with decision making and with action begin at about the same time. If the decision making component ends before the action component, the probability of a correct action is high. If the decision making component ends after the completion of the action component, the probability of an error is high. Hence, proper monitoring of the EEG can be used to assess the probability of correct operator action, without knowing the correct operator action. With a high probability of error, the operator could, for example, be asked to

reconsider his choice. Finally, a new method of monitoring probability assessment from the electroencephalogram has been demonstrated. When people are required to infer probabilities, a component of the electroencephalogram is a very good indicator of the "true" probability, often better than their articulations. The electroencephalogram measure does not demonstrate the so-called gambler's fallacy, "There have been ten heads, so tails must be coming up next."

21. Ultra-Rapid Text Presentation - A new method of computer-based text presentation has been demonstrated that increases reading rates by a factor of two to four, without harming comprehension and with an improvement in memory by a factor of two. The technique is based on the observation that the limiting factor in reading is movement of the eyes. The new method does not require the reader to move his eyes, and presents the words of the text serially at one position on a display at a rate of 12 to 24 words per second. In a number of cases, pictures representing concepts are presented instead of words; e.g., a picture of a tank rather than the word "tank."

B. PROGRAMS TRANSFERRED TO OTHERS

1. Packet Satellite Technology - The packet satellite technology will be transferred to the Defense Communications Agency during FY 1979. The packet satellite technology will be utilized by DARPA and DCA as part of a joint project in integrated data/voice packet networks.

2. Intelligent Terminal Program - Techniques and software developed in the Intelligent Terminal program have been transferred and are in daily use at NSA, CIA and several Navy sites. They are being used to evaluate the utility of advanced human interface capabilities for the early 1980's.

3. Automatic Morse Interpretation - During FY 1978, the experimental Morse understanding system will be tested, documented, and transferred to prospective users (the National Security Agency) who will participate in this process. The users will assume responsibility for further development of this technology during FY 1979.

4. Long Range Imaging Radar - Under this program, DARPA successfully developed hardware and techniques for the identification of space objects. The radar has been recently transferred to the Air Force (SAMSO) in order to exploit the hardware for data gathering purposes and to develop additional system capabilities.

5. Special Communication Technology - This effort developed advanced communication technology and has been transferred to Naval Electronic Laboratory Center's Advanced Development Model effort.

6. Pulsed Chemical Laser - Key physics demonstrations have established the potential of pulsed chemical devices. Continued efforts will be carried out by the Air Force and Navy High Energy Laser Programs.

7. Laser Propagation - This DARPA program has succeeded in resolving key issues in the propagation of laser beams within the atmosphere. Continued work in this area will be part of continuing DoD High Energy Laser Programs.

8. Integrated Communications-Navigation System (ICNS) - The ICNS for the mini-remotely piloted vehicle has completed its laboratory and field testing and has met or exceeded all of the required specifications. Automatic acquisition, resistance to jamming, aircraft location and the ability to pass both digital data and video signals have been demonstrated. The program is now being transferred to the Army, and it is expected that flight tests in both manned aircraft and the Aquila remotely piloted vehicle will be conducted in early CY 1978. The ICNS is a system in which modulation and adaptive antennas have been successfully combined, and it represents the state-of-the-art in anti-jam technology, both as to performance and as to size, weight and cost. It is being considered for use in several other systems.

9. Infrared Mortar Locator - As part of the Hostile Weapons Location System (HOWLS) program, DARPA developed a mortar locating system which combined an infrared detector array and a laser range-finder. Field tests with an experimental version of the system demonstrated that reliable detections could be made, and that mortar

locations could be determined with accuracy. A careful analysis of weather in central Europe has shown that the system should be usable 90 percent of the time. The program has been transferred to the Army Night Vision Laboratory for follow-on development of an operational version of the device.

10. Tunnel Detection - Tunnel detection and location technology has been significantly improved by development of surface and down hole techniques. An airborne tunnel locating technique has been demonstrated which can be effective. Tunnel Detection Technology has been transferred to the Army Missile Research and Development Command. Complete test results and a summary of the DARPA tunnel locating program is being prepared this year.

11. Infrared Laser Components and Diagnostics - The infrared laser windows, coatings and mirrors program has developed window materials with absorptions of 10^{-4}/cm or less at all major infrared high power laser wavelengths. Thin films for window anti-reflection coatings and mirror reflection enhancement have been solved for all wavelengths except that for high frequency (2.8 micrometers) lasers which require continued research. Component research on windows and mirrors at other than high frequency wavelengths have been transferred to the Services (primarily the Air Force) since the problems remaining are specific to individual systems.

12. Brittle Materials Design - The DARPA brittle materials design program is being transferred to the Department of Energy at the conclusion of successful ceramic turbine technology demonstrations

designed to show concept feasibility. Previously (FY 1976), ceramic stator vanes for a 30 megawatt central power station turbine generator had demonstrated 200 hours durability in a simulated service environment. This effort is being continued under utility industry sponsorship as a contributed component of the Department of Energy high temperature turbine program. Under separate effort, a 200-hour duty cycle for an automotive ceramic turbine engine (220 horse-power) will be demonstrated on all-ceramic rotors subjected to a combustion environment in FY 1978. If successful, the principal objectives of the DARPA program for ceramic process development, design modeling and performance testing for advanced turbine engines will have been met and continued automotive ceramic engine development will be assumed by the Department of Energy under their advanced heat engine program.

13. Integrated Circuit Process Measurement and Control - The semiconductor industry has been outstandingly successful in providing commercial integrated circuits with increasing performance at decreasing costs. These devices, however, do not generally meet military systems requirements such as operating temperature, range and resistance to environmental effects. To qualify parts for military use, expensive test schemes have been devised which do not always provide parts with the desired performance and reliability. In FY 1974, DARPA initiated a program with the National Bureau of Standards to develop semiconductor process measurement and control technology which would provide a vastly improved basis for procuring military integrated circuits having "built-in" rather than expensive and inadequately "tested-in" performance

and reliability. Program output to date has avoided substantial costs and schedule slippages in DoD missile procurements; increased reliability of fielded systems; greatly expanded procured quantities of military-qualified integrated circuits; and developed highly effective military standards, specifications, and qualification tests. During FY 1978, transfer of the program is being initiated with Tri-Service support. The principal technical activities during FY 1979, which will mark the final year of DARPA support, will be completion of semiconductor photomask line width standards and measurement techniques and development of test pattern structures for process validation and vendor qualification.

14. Two-Micron Photocathodes - The effort to extend the photo-response of photocathode structures to night-time "air-glow" photons having wavelengths longer than one micron has achieved its objective, with a measured external quantum yield (electrons emitted per incident photon) of 1.0 percent for photons of 1.7 μm microns wavelength while operating at 300°K. Useful photoemissive yield at wavelengths beyond about 1.2 μm at any operating temperature has not been demonstrated by any other research effort. Transfer to the DARPA agent, the Army Night Vision Laboratory, was initiated in FY 1978 through joint funding as a result of progress achieved to that time. The Night Vision Laboratory will assume full program responsibility in FY 1979.

15. Pyroelectric Vidicon - The effort to develop a low-cost, uncooled, thermal imaging system based on a pyroelectric vidicon has demonstrated major progress in increasing both spatial resolution and thermal sensitivity. It is now feasible to consider

use of these devices for a range of applications, such as base security surveillance and missile guidance, where performance would be adequate and the total number of systems needed make cost a predominant factor in technology selection. The DARPA agent, the Night Vision Laboratory, has jointly funded this effort and will assume total program responsibility in FY 1979. A study of infrared sensitive pyroelectric materials, with the goal of developing guidelines to provide materials having substantially greater pyroelectric sensitivity has also shown major progress with the identification of a promising new class of pyroelectric materials, the "improper ferroelectrics." These studies will continue through FY 1979 under DARPA sponsorship.

C. PROGRAMS TERMINATED

1. Advanced Submersible Technology - Research this year will entail completion of the flow tube experiment and the body tow tests, participation in Navy sponsored testing of one or two of the tow tank models built by DARPA in FY 1977, and analytic and numerical investigations of the critical physical issues perceived to be limiting laminar flow control. All the findings of the program will be assessed and consolidated in a final laminar flow technology status report at the end of FY 1978. Although this research has been terminated, applications of partial laminar flow for sonar noise quieting and to lower vehicle speeds with favorable hydrodynamic shapes may still be attractive.

2. Learning Strategies - In the past ten years, both aptitude and achievement scores of college-bound high school students have dropped dramatically. At the same time, the sophistication of our technological society has increased. Thus, DoD will have to man our increasingly complex weapon systems with trainees of potentially less aptitude and achievement. One approach that has been investigated to overcome this problem was to develop and evaluate instructional materials designed to teach basic intellectual and affective skills. These skills are called "learning strategies," since the intent is to make learning more efficient and effective. Preliminary evidence indicated a potential fourfold improvement in the intellectual performance of trainees instructed in learning strategies as compared to the group that did not receive such training. Because of the broad

nature of the problem, in both military and civilian sectors, and since the military impact was long-range and would require extensive institutional research and development to exploit fully, the DARPA program has been terminated.

3. Strategic Communications Technology - Detailed calculations of space-based proton beam interactions with the magnetosphere to create ultra low frequency communications showed that the technical risk in this area was unacceptably high and therefore this effort has been terminated.

4. Chemical Visible Lasers - After several years of exploratory research on electronic chemical lasers, no candidates demonstrated significant impact relative to other approaches and the program has been terminated.